Green Building Technologies

The U.S. EPA Environmental Technology Verification (ETV) Program, through cooperative agreements with non-profit testing laboratories, has verified nine green building technologies[1]: two fuel cells and six microturbine/combined heat and power (CHP) technologies that generate energy at the point of use, and one ground-source heat pump for onsite water heating. ETV has also signed contracts with three vendors to verify mold resistant wallboard and recently updated the protocol for biological and aerosol testing of ventilation air cleaners, in preparation for testing in this area.

Green building is the "practice of creating healthier and more resource efficient models of construction, renovation, operation, maintenance, and demolition" (U.S. EPA, 2006c). In the United States, buildings account for 39% of total energy use, 12% of total water consumption, 68% of total energy consumption, and 38% of carbon dioxide (CO_2) emissions. They also consume enormous amounts of raw material and energy during construction and generate a large amount of waste during demolition (U.S. EPA, 2006d). Thus, the ETV-verified green building technologies could provide significant environmental, economic, and human health benefits.

Table 1. Verified Green Building Energy Technologies

Microturbines and CHP Systems	Electricity Generating Capacity (kW)
Mariah Energy Corporation Heat PlusPower™ System[A]	30
Ingersoll-Rand Energy Systems IR PowerWorks™ 70 kW Microturbine System[A]	70
Honeywell Power Systems, Inc. Parallon® 75 kW Turbogenerator	75
Honeywell Power Systems, Inc. Parallon® 75 kW Turbogenerator with CO Emissions Control	75
Capstone Turbine Corporation 30 kW Microturbine System[A]	30
Capstone Turbine Corporation 60 kW Microturbine CHP System[A]	60
Fuel Cells	**Electricity Generating Capacity (kW)**
Plug Power SU1 Fuel Cell System	6
UTC Fuel Cells, LLC PC25™ Fuel Cell[B]	200
Ground-Source Heat Pump Water Heating System	**Rated Performance & Heating Capacity**
ECR Technologies, Inc. EarthLinked® Water Heating System	36,000 Btu and 60 gallons/hour

[A] Includes heat recovery for CHP
[B] UTC Fuel Cells, LLC was known as International Fuel Cells Corporation when it was verified in 1998. The technology has since been renamed as the PureCell™ 200.
kW = kilowatts, Btu = British thermal unit

Distributed Power Generation at a Glance

EPA estimates that, in 2002, the United States emitted almost 6.4 billion tons of CO_2 and nearly 22 million tons of nitrogen oxide (NO_X). Electricity generation accounted for 39% of the total CO_2 emissions and 21% of the total NO_X emissions. Other pollutants emitted during electricity generation include carbon monoxide (CO) and total hydrocarbons (THC). Each of these emissions can have significant environmental and health effects. CO_2 is a greenhouse gas linked to global climate change. CO, THC, and the various compounds in the NO_X family cause a wide variety of environmental and health-related impacts (U.S. EPA, 2006b).

Fuels cells and microturbines use hydrogen and natural gas to generate electricity, and ground sourced heat pumps transfer heat between the earth and buildings for heating/cooling or hot water heating. In addition to the efficiencies passed on by the technologies themselves, power transmission losses, which can be in the range of 4.7% to 7.8%, can be avoided and reliance on electricity from large electric utility plants can be reduced. When well-matched to a facility's needs in a properly designed combined heat and power (CHP) application, net fuel consumption and overall emissions can also be reduced. Fuel cells and microturbines can also operate using biogas from animal waste, etc., reducing natural resource consumption (U.S. EPA, 2006b).

Tables 2 and **3** summarize the performance data for the verified technologies. Verification reports are located at: http://www.epa.gov/etv/verifications/vcenter3-17.html, http://www.epa.gov/etv/verifications/vcenter3-13.html, and http://www.epa.gov/etv/verifications/vcenter3-18.html. These reports fully describe the verification tests and results. Collaborators included the State of Colorado, the New York State Energy Research and Development Authority (NYSERDA), New York City, and the EPA CHP Partnership.

Verified fuel cell

[1] The ETV Program operates largely as a public-private partnership through competitive cooperative agreements with non-profit research institutes. The program provides objective quality-assured data on the performance of commercial-ready technologies. ETV does not endorse the purchase or sale of any products and services mentioned in this document.

Table 2. Performance of Verified Energy Technologies		
Parameters	Fuel Cells	Microturbines
Power Production[A]		
Electrical efficiency	23.8% to 38.0%	20.4% to 26.2%
Potential thermal efficiency	56.9%[B]	7.2% to 47.2%[C]
Potential total system efficiency	93.8%[B]	33.4% to 71.8%[C]
Emissions Rates		
CO_2, lbs/kWh[D]	1.31 to 1.66	1.34 to 3.90
NO_X, lbs/kWh[D]	NA	4.67×10^{-5} to 4.48×10^{-3}

[A] At full load, under normal operation.
[B] The potential for heat recovery was verified in one of the three tests.
[C] For the four systems with heat recovery
[D] lbs/kWh = pounds per kilowatt-hour
Source: U.S. EPA 2006b

Table 3. Performance of Verified Ground-Source Heat Pump Water Heating System	
Thermal	
Water heating capacity[A] - Low temperature short-term test - Elevated temperature short-term test	 35100 ± 1300 Btu/h 32300 ± 1100 Btu/h
Coefficient of Performance	
Coefficient of performance - Low temperature short-term test - Elevated temperature short-term test - Long-term in-service test[B]	 3.58 ± 0.12 2.7 ± 0.1 4.43 ± 0.09
Change in average system efficiency[B,C]	3.00 ± 0.07%
Change in electrical power consumption[C,]	75 ± 6%
Emissions	
CO_2 emissions reductions, lbs/kWh[C]	1390
NO_X emission reductions, lbs/kWh[C]	2.96

[A] Results are not adjusted to account for the average standby heat loss, 490 ± 90 Btu/h.
[B] Coefficient of performance only looks at the performance of the device under testing, while average system efficiency characterizes the performance of the whole system.
[C] Long-term test result.
Source: Southern Research Institute, 2006.

References

Southern Research Institute, 2006. *ETV Verification Statement: Ground-Source Heat Pump Water Heating System*. September.

U.S. EPA, 2006a. *Project Summary: Verification of Microbial Resistant Building Materials - Gypsum Wallboard*.

U.S. EPA, 2006b. *ETV Case Studies: Demonstrating Program Outcomes, Volume II*. EPA/600/R-06/082. September. (Primary source)

U.S. EPA, 2006c. *Green Buildings.* Last updated 17 October. http://www.epa.gov/greenbuilding/index.htm.

U.S. EPA, 2006d. *Why Build Green.* Last updated 17 October. http://www.epa.gov/greenbuilding/pubs/whybuild.htm.

Selected Outcomes of Verified Distributed Energy Technologies

Available sales data indicate that a capacity of 28 megawatts (MW) of ETV-verified fuel cells and microturbines (in CHP applications) have been installed in the United States since the verifications were completed. ETV estimates that these systems have:

- Reduced CO_2 emissions by 53,000 tons per year and NO_X by 240 tons per year, with associated climate change, environmental, and health benefits.
- Increased utilization of renewable fuels resulting in reductions in the consumption of natural resources. (Note: Fuel cells that utilize anaerobic digester gas are responsible for 2 MW of the capacity listed above and 14,000 tons per year of the CO_2 reductions.)

Assuming annual sales continue at the same rate as in 2005, ETV estimates the total installed capacity of ETV-verified fuel cells should reach 89 MW in the next five years, reducing CO_2 by 191,000 tons per year and NO_X by 600 tons per year (U.S. EPA, 2006b).

Microbial Resistant Wallboard at a Glance

Approximately 90% of interior finished surfaces are covered with gypsum products and 40% of the homes in North America contain fungal growth on the gypsum wallboard. Each year millions of tons of wallboard are disposed of as scrap in landfills due to mold. Mold may also pose a potential health risk to sensitive populations, such as asthmatics (www.epa.gov/asthma) .

A number of microbial-resistant wallboards have been introduced to the market that incorporate either the removal of the microbial growth substrates or the addition of the antimicrobial agents. ETV plans to evaluate the performance of some of these products, including their ability to support fungal (mold) growth and resistance to moisture uptake (U.S. EPA, 2006a).

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EPA/600/F-06/016
October 2006

www.epa.gov/etv